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ABSTRACT:

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H4R RPX
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(56) Documents Cited
GB 2147165 A US 5396562 A US 4730165 A
US 4562591 A

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UK CL (Edition O) G5J JEGF JESG , H3G GPX GPXX GSX , H4R RPX RSS RSX
INT CL[6] H03G , H04H , H04S
Online: WPI, JAPIO, INSPEC

(54) Digital audio processing

(57) In a digital audio processor of sampled digital audio signals, the peak or envelope of the signals are detected at 30 and a variable gain is applied at 10 to the digital audio signal. A dynamics processing circuit 50 under the control of circuit 60 controls the gain in such a way that for detected peaks or envelopes below and above first, second thresholds respectively the applied gain is linearly related to the envelope signal with a first, second predetermined slope and in between the thresholds the slope of the gain vs detected envelope varies monotonically (fig.3 not shown) to provide a soft knee and and minimises subjectively disturbing audible distortion. Circuits 40, 70 provide a linear to logarithmic or decibel conversion and decibel to linear conversion. The circuit 50 may include (fig.4 not shown) a calculating circuit followed by a pair of multiplexers or switching circuits. The processor may form part of a digital audio mixing console.

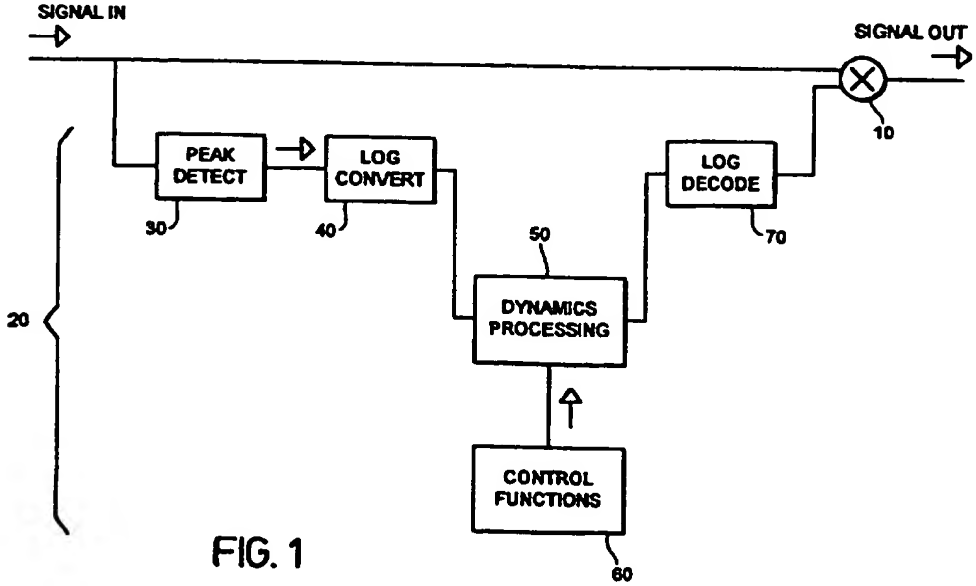

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

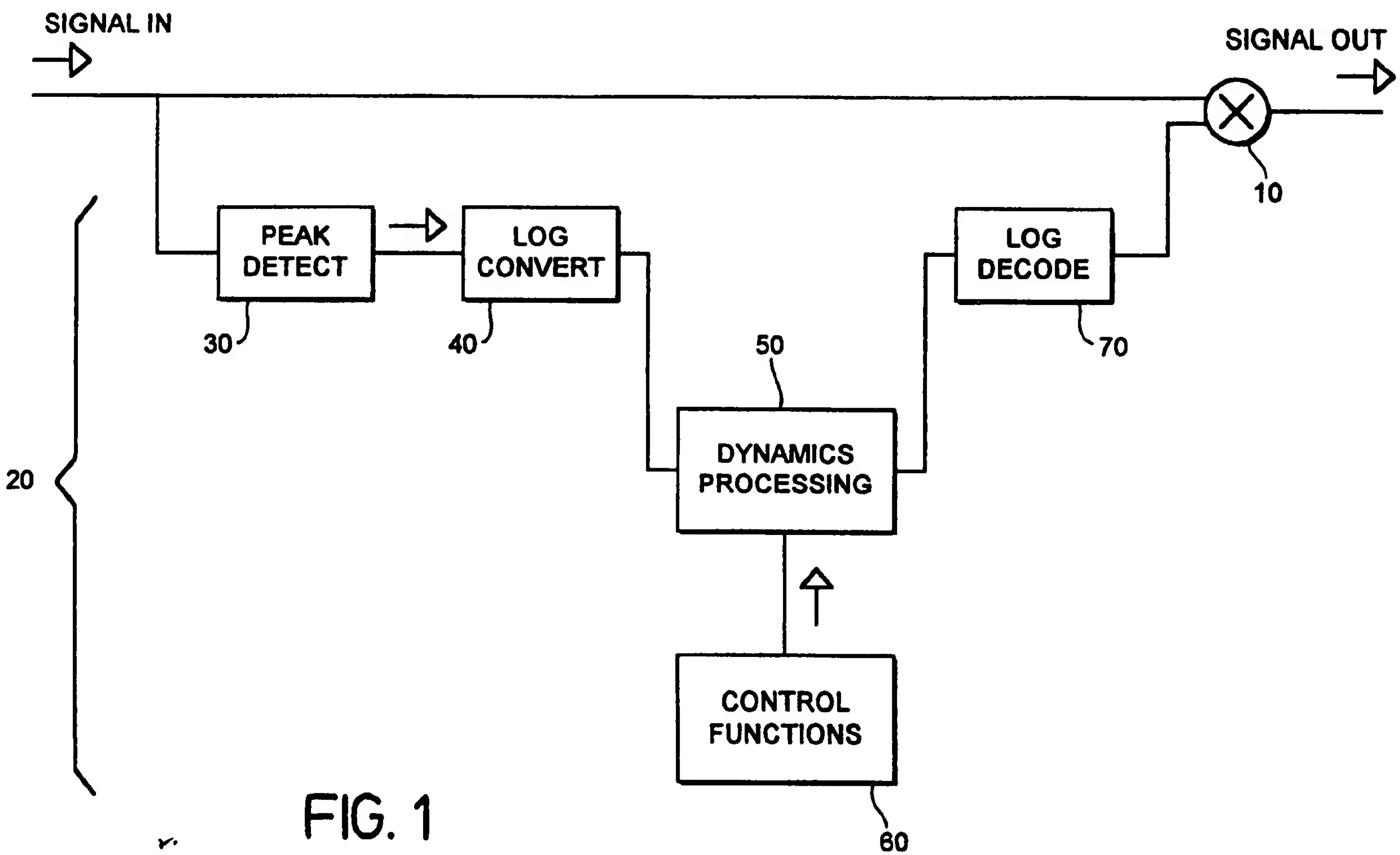
SIGNAL IN
SIGNAL OUT
10
PEAK DETECT
30
LOG CONVERT
40
DYNAMICS PROCESSING
50
LOG DECODE
70
CONTROL FUNCTIONS
60
20

FIG. 1

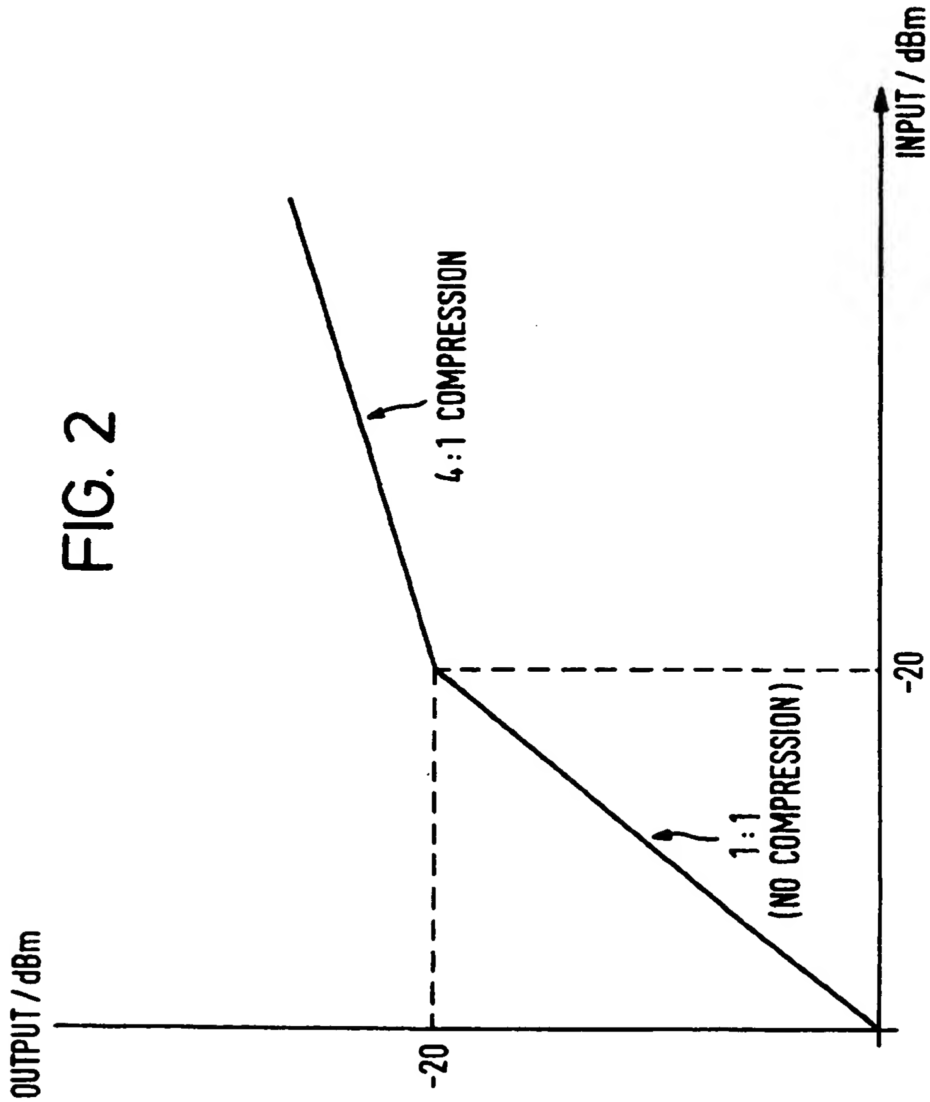

FIG. 2

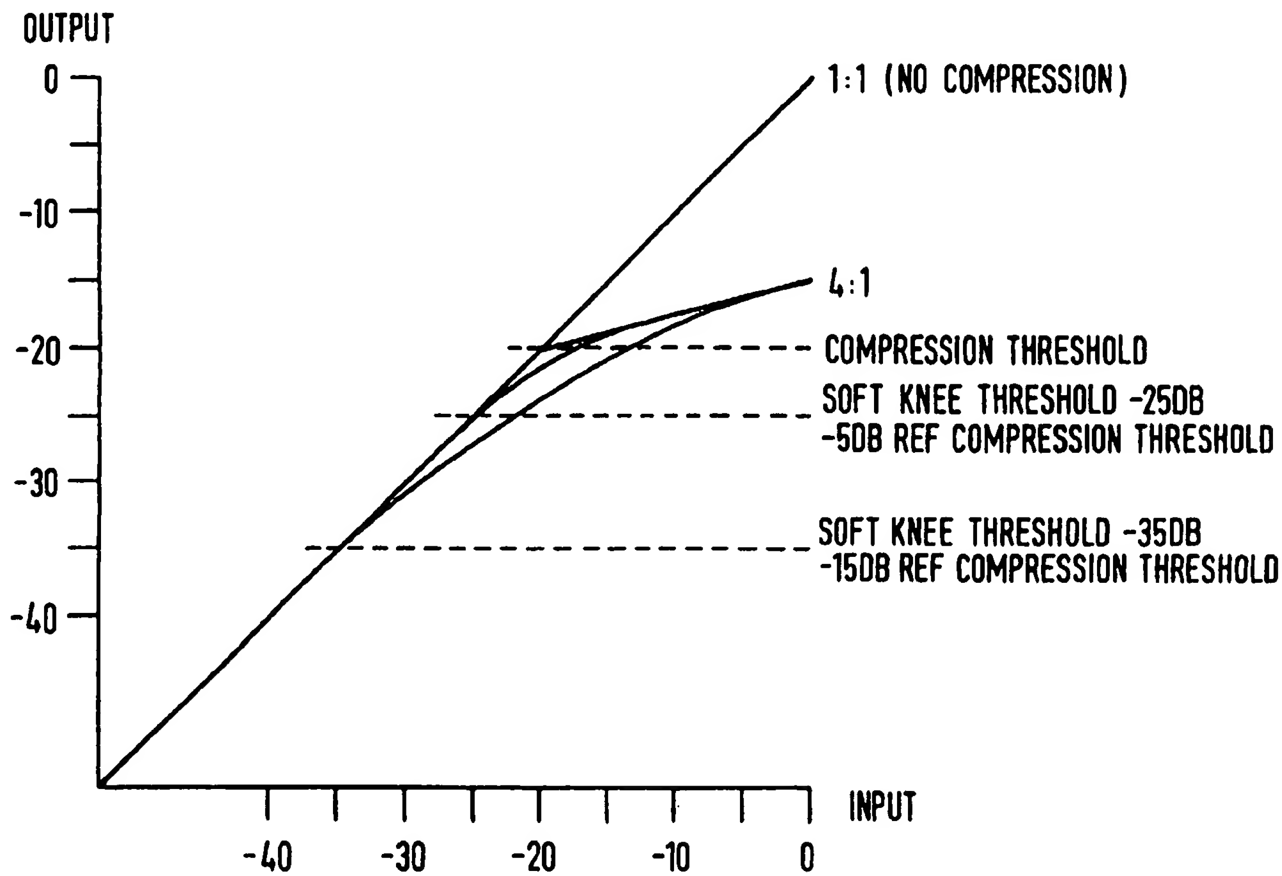
OUTPUT
0
-10
-20
-30
-40
1:1 (NO COMPRESSION)
4:1
COMPRESSION THRESHOLD
SOFT KNEE THRESHOLD -25DB
-5DB REF COMPRESSION THRESHOLD
SOFT KNEE THRESHOLD -35DB
-15DB REF COMPRESSION THRESHOLD
INPUT
-40
-30
-20
-10
0

FIG. 3

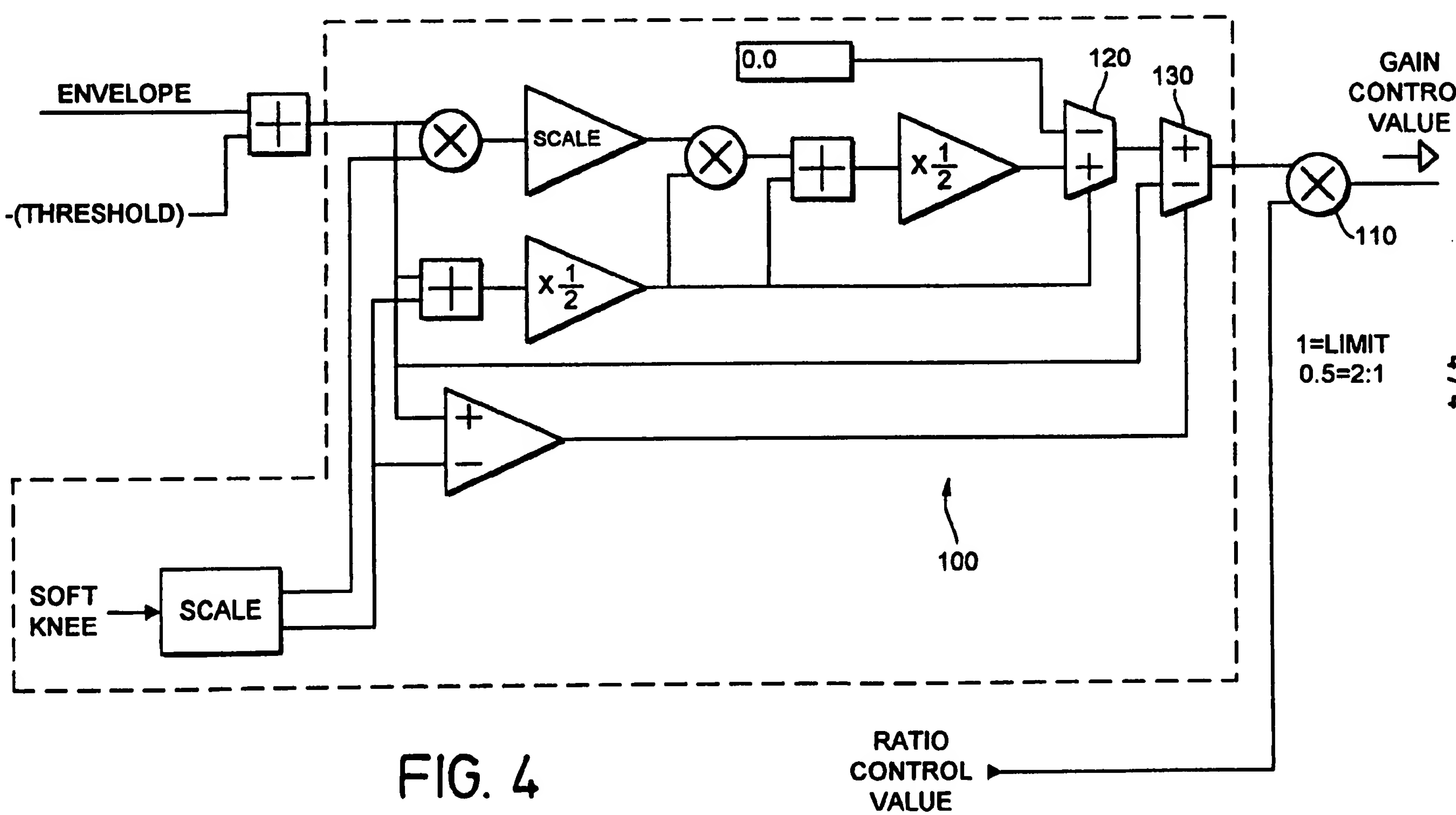
ENVELOPE
-(THRESHOLD)
SCALE
x 1/2
x 1/2
0.0
120
130
GAIN CONTROL VALUE
110
1=LIMIT
0.5=2:1
100
SOFT KNEE
SCALE
RATIO CONTROL VALUE

FIG. 4

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DIGITAL AUDIO PROCESSING

This invention relates to the processing of digital audio signals.

In many modern audio signal processing devices, such as audio mixing consoles, audio processing operations which had previously been carried out in the analogue domain are now performed on sampled digital audio signals.

An example of this is the "dynamics" section of a digital audio mixing console. Dynamics processing refers to a family of processing techniques generally having a non-linear effect on the audio signal (compared with the substantially linear techniques of simple gain adjustment and additive mixing). In general, effects classified as "dynamics" tend to have a distorting effect on the sound represented by the audio signal, albeit often a pleasing or useful distortion. For example, the gain applied to an audio signal might be non-linearly adjusted (or "compressed") so that the audio signal has a more constant level – alleviating the level variations which might result as a performer moves towards and away from a microphone.

Figure 1 of the accompanying drawings schematically illustrates such a processor in which an input digital audio signal (for example, a digital audio signal sampled at a 48kHz sampling rate to 16 bit resolution) is supplied in parallel to a multiplier 10 and to a processing chain 20.

The processing chain 20 comprises a peak (or envelope) detector 30, a logarithmic (linear to decibel) converter 40, a dynamics processing element 50, a control circuit 60, and a logarithmic (decibel to linear) converter 70.

The output of the logarithmic converter 70 is supplied as a second multiplicand to the multiplier 10, to be multiplied by sample values of the input digital audio signal. In this way, the output of the processing chain 20 provides a gain control for the input digital audio signal.

The dynamics processing element 50 operates in the logarithmic domain, i.e. it receives envelope values and generates gain control values in decibels rather than as linear measures. This is so that the time constants, control values and other constants used by the dynamics processing element relate to a decibel law directly, which in turn makes the implementation of the dynamics processing element more simple and intuitive.

The dynamics processor of Figure 1 may be arranged to provide various different dynamics processing functions, depending on the way in which the dynamics processing element 50 generates an output gain control value in response to the detected envelope of the input digital audio signal. For the present explanation, consider the simple example whereby the dynamics processing element is arranged as a threshold compressor to provide an output of "0 decibels" (no compression) when the detected input envelope is under, say, −20dB and to provide an output indicative of, say, a 4:1 compression for higher detected input envelopes. (In general, the threshold level and the amount of applied compression will be selectable by the user under the control of the control circuit 60). This example compression response is illustrated schematically in Figure 2 of the accompanying drawings.

The gain control value output by the dynamics processing element 50 is then converted to a linear control value by the logarithmic converter 70 and supplied as a multiplicand to the multiplier 10.

This invention provides digital audio processing apparatus comprising:

means for detecting the magnitude of an input digital audio signal; and

a variable gain element for applying a gain to the input digital audio signal dependent on the detected magnitude of the input digital audio signal, in which:

(i) the applied gain is linearly related to the envelope signal with a first predetermined slope, for detected magnitudes below a first threshold magnitude;

(ii) the applied gain is linearly related to the envelope signal with a second predetermined slope, for detected magnitudes above a second threshold magnitude higher than the first threshold magnitude; and

(iii) for detected magnitudes from the first threshold magnitude to the second threshold magnitude, the slope of the applied gain with respect to detected magnitude varies monotonically from the first predetermined slope to the second predetermined slope.

The invention recognises that the gain slope discontinuity (or "knee") at the onset of compression in the previously proposed compression processor described above can lead to subjectively disturbing audible distortion of the compressed signal.

The invention addresses this problem by providing a digital compression processor with a "soft knee" – that is, a *range* of levels over which the slope of the

applied gain with respect to detected envelope magnitude monotonically increases (or decreases) from the first to the second slope values. This reduces the *rate of change* of gain slope with level (which is very high in a previously proposed system having an abrupt change of gain as shown in Figure 2), which in turn reduces the audible distortion which the compressor applies to the digital audio signal.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a dynamics processor;

Figure 2 is a schematic graph of a simple compression response of the processor of Figure 1;

Figure 3 is a schematic graph of a compression response provided by embodiments of the invention; and

Figure 4 is a schematic diagram of the circuitry of a dynamics processing element for generating the response of Figure 3.

The so-called "soft knee" processing is carried out by a calculation performed by the dynamics processing element 50 of Figure 1, in response to control parameters supplied by the control circuit 60.

In the following discussion, the level threshold above which the input digital signal is to be compressed is L_{Thr}; the input level is L_{in}; the excess level is L_{ex}; and a "soft knee" region is e_s. The quantity $(L_{in} - L_{Thr})$ is referred to as x.

Considering the relationship between L_{ex} and x, which in a previously proposed compression processor (having a gain discontinuity at the onset of compression) obeys the relationship:

$$\text{if } x < 0 \quad \text{then} \quad L_{ex} = 0$$
$$\text{if } x >= 0 \quad \text{then} \quad L_{ex} = x$$

In the present embodiment, this relationship is changed to introduce a new function F(x) when x is within the "soft knee" amount e_s of zero. Thus,

$$\text{if} \quad x < -e_s \quad \text{then} \quad L_{ex} = 0$$
$$\text{if} \quad -e_s <= x < e_s \quad \text{then} \quad L_{ex} = F(x)$$

if	$x >= e_s$	then	$L_{ex} = x$

The function F(x) is selected so that the value of F(x) **and** the first derivative of F(x) (i.e. F'(x)) are continuous with the linear sections at values of x less than $-e_s$ and at values of x greater than or equal to e_s. Thus, the following conditions are applied:

$$F(-e_s) = 0$$
$$F'(-e_s) = 0$$
$$F(e_s) = e_s$$
$$F'(e_s) = 1$$

A large family of functions fit these conditions, but for convenience of implementation (i.e. calculation be the dynamics element 50), a low order (quadratic) polynomial is used:

if	$x < -e_s$	then	$L_{ex} = 0$
if	$-e_s <= x < e_s$	then	$L_{ex} = x^2/4e_s + x/2 + e_s/4$
if	$x >= -e_s$	then	$L_{ex} = x$

This relationship is illustrated schematically in the graph of Figure 3, for two values of e_s, 5dB (the upper curve) and 15dB (the lower curve).

Figure 4 is a schematic diagram of the circuitry of a dynamics processing element for generating this compression response.

The circuit of Figure 4 receives an envelope value from the logarithmic converter 40, a threshold value (in fact a negative value), a "soft knee" value (e_s) and a ratio control value, all from the control circuit 60.

The threshold value is added to the envelope (in effect, subtracting the threshold from the envelope value) and the resulting value is passed, with the scaled soft knee value e_s to a calculation circuit which performs the calculations described above.

The resulting quadratic expression from the calculating circuit is passed to a multiplier 110 where it is multiplied by the ratio control value to scale the response to the desired degree of compression (e.g. the ratio control value would be 0.25 for

the 4:1 asymptotic compression shown in Figure 3).

At the output of the calculating circuit are two multiplexers, 120, 130. If the value (envelope – threshold) is less than $-e_s$, then the multiplexer 120 passes a value of zero instead of the quadratic expression. If the value (envelope – threshold) is greater than $+e_s$, then the multiplexer 130 passes the (envelope – threshold) value.

CLAIMS

1. Digital audio processing apparatus comprising:

means for detecting the magnitude of an input digital audio signal; and

a variable gain element for applying a gain to the input digital audio signal dependent on the detected magnitude of the input digital audio signal, in which:

(i) the applied gain is linearly related to the envelope signal with a first predetermined slope, for detected magnitudes below a first threshold magnitude;

(ii) the applied gain is linearly related to the envelope signal with a second predetermined slope, for detected magnitudes above a second threshold magnitude higher than the first threshold magnitude; and

(iii) for detected magnitudes from the first threshold magnitude to the second threshold magnitude, the slope of the applied gain with respect to detected magnitude varies monotonically from the first predetermined slope to the second predetermined slope.

2. Apparatus according to claim 1, in which, for detected magnitudes from the first threshold magnitude to the second threshold magnitude, the slope of the applied gain with respect to detected magnitude varies linearly with respect to detected magnitude from the first predetermined slope to the second predetermined slope.

3. Apparatus according to claim 1 or claim 2, in which the second predetermined slope represents a higher degree of compression than the first predetermined slope.

4. Digital audio processing apparatus substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Claims searched: ALL

Examiner: Mr.SAT SATKURUNATH
Date of search: 6 August 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4R: RSS, RSX, RPX;H3G: GSX, GPX, GPXX;G5J:JESG, JEGF

Int Cl (Ed.6): H03G, H04H, H04S

Other: Online: WPI, JAPIO, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2147165 A	BBC - see especially figures 1, 6 and 7	1
A	US 5396562	PIONEER - see figures 1, 2	1
X	US 4730165	MATSUSHITA - see especially figures 9, 18 and lines 32-34 in column 8	1
A	US4562591	PHILIPS - see especially fig.1	1

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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E Patent document published on or after, but with priority date earlier than, the filing date of this application.